

**CROSSLINKABLE MATERIALS FOR ORGANIC LIGHT EMITTING  
DEVICES AND METHODS**

**RELATED APPLICATIONS**

- 5   **[0001]**    This application claims priority from, and incorporates by reference, US Provisional application serial No. 60/461,444, filed April 9, 2003.

**FIELD OF THE INVENTION**

- 10   **[0002]**    The present invention relates generally to crosslinkable charge transporting or light emitting materials, polymers formed from the same, methods of forming the polymers, and devices using the polymers.

**BACKGROUND**

- 15   **[0003]**    Different types of materials have different properties that often lend themselves to certain application better than other materials. For example, calamitic liquid crystal organic light-emitting device (OLED) charge transport and light emitting materials have a number of properties that may be advantageously used in, for example, display devices as either the display elements or as a backlight. However, for some applications the use of such a material may be disadvantageous or even impossible.
- 20    Accordingly, there is a need in the art for additional materials that have different properties.

**SUMMARY OF THE INVENTION**

[0004] The present invention provides charge transport or light emitting polymerizable materials having photocrosslinkable dienes.

[0005] The present invention also provides charge transport or light emitting materials formed from the polymerizable charge-transport or light emitting materials.

[0006] The present invention also provides a process of photopolymerizing the materials.

[0007] The present invention also provides devices formed from a charge transport or light emitting layer.

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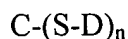
**BRIEF DESCRIPTION OF THE DRAWINGS**

[0008] FIG. 1 illustrates an exemplary embodiment including transport layers and emissive layers.

15 **DETAILED DESCRIPTION**

[0009] In an aspect, the present invention provides novel charge transporting or light emitting photopolymerizable materials, comprising: reactive non-mesogenic compounds having photocrosslinkable dienes.

[0010] In another aspect, the present invention provides suitable reactive non-mesogenic compounds having the following formula:



wherein:

C is a chromophore;

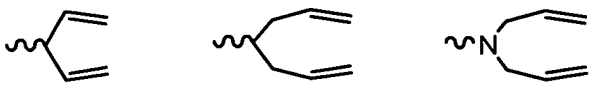
S is a spacer;

D is a non-conjugated diene susceptible to photopolymerization; and,

n is selected from 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10.

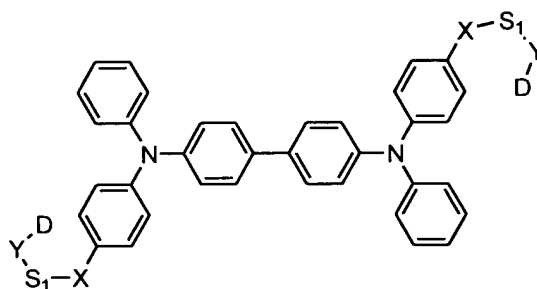
[0011] Chromophore C may be selected from: aryl substituted fluorene; 4,4',4''-  
5 tris[N-(1-naphthyl)-N-phenyl-amino]triphenylamine; and, bis-triphenylamine, wherein  
from 0-2 hydrogen atoms on chromophore C are replaced by a group selected from  
deuterium, F, and CH<sub>3</sub>. Aryl substituted fluorene is intended to mean that the fluorene  
unit is substituted with 1-2 first aromatic rings, which are independently selected from  
phenyl, naphthyl, and 5-10 membered aromatic heterocycles consisting of carbon atoms  
10 and 0-4 heteroatoms selected from O, S, and NH. Examples of heterocycles include, but  
are not limited to, thienyl, pyridyl, pyridazinyl, pyrimidinyl, pyrazinyl, and triazinyl.  
Preferably, the first aromatic rings are phenyl or thienyl. It is also preferable that the first  
aromatic rings are themselves independently substituted with a second aromatic ring.  
The second aromatic rings are independently selected from phenyl, naphthyl, and 5-10  
15 membered aromatic heterocycles consisting of carbon atoms and 0-4 heteroatoms  
selected from O, S, and NH. Preferably, the second aromatic rings are phenyl or thienyl.  
Both the first and second aromatic rings may be substituted with 0-2 groups selected from  
C<sub>1-12</sub> alkyl (branched or linear), C<sub>1-12</sub> alkenyl (branched or linear), C<sub>1-12</sub> alkoxy (linear or  
branched), phenyl, naphthyl, bi-phenyl, and thienyl. Spacer S may be an alkylene (linear  
20 or branched) or alkenylene (linear or branched) group having 2, 3, 4, 5, 6, 7, 8, 9, 10, 11,  
12, 13, 14, or 15 carbon atoms. From 0, 1, 2, to 3 of the carbon atoms of spacer S are  
replaced by a heteroatom selected from O, S, and NR, wherein R is selected from H,  
CH<sub>3</sub>, C<sub>2</sub>H<sub>5</sub>, n-C<sub>3</sub>H<sub>7</sub>, and i-C<sub>3</sub>H<sub>7</sub>, preferably CH<sub>3</sub>, C<sub>2</sub>H<sub>5</sub>, n-C<sub>3</sub>H<sub>7</sub>, and i-C<sub>3</sub>H<sub>7</sub>. From 0, 1, to

2 carbon atoms of spacer S may be substituted by a carbonyl group. Diene D may be

selected from: , provided that D forms other than an O-N, S-N, or N-N bond with spacer S. Variable n may be selected from 2, 3, 4, 5, and 6.

5 **[0012]** The terms alkyl, alkylene, alkenyl, and alkenylene, unless otherwise specified, include both linear and branched groups having the defined number of carbon atoms.

**[0013]** In another aspect, the present invention provides novel reactive non-mesogenic compounds of formula I:



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I

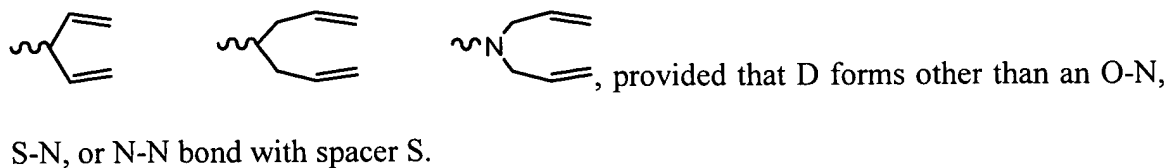
wherein:

each X is independently selected from CH<sub>2</sub>O, CH<sub>2</sub>, and CH<sub>2</sub>NR, wherein R is selected from H, CH<sub>3</sub>, C<sub>2</sub>H<sub>5</sub>, n-C<sub>3</sub>H<sub>7</sub>, and i-C<sub>3</sub>H<sub>7</sub>; preferably CH<sub>2</sub>O;

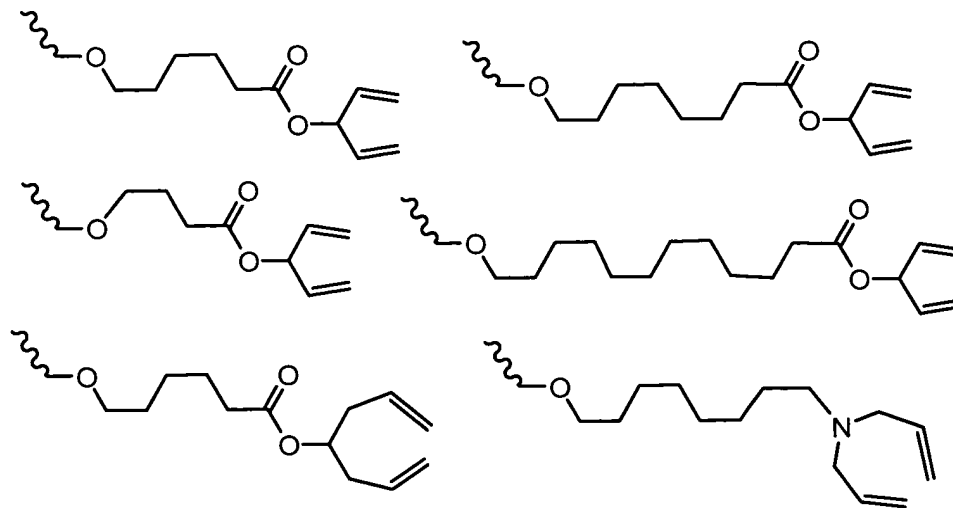
each S<sub>1</sub> is independently selected from an alkylene group (linear or branched) and  
15 an alkenylene group (linear or branched) having 2, 3, 4, 5, 6, 7, 8, 9, 10, or 11 carbon atoms;

each Y is independently selected from CH<sub>2</sub>, O, CO<sub>2</sub>, and S; preferably CO<sub>2</sub> and,

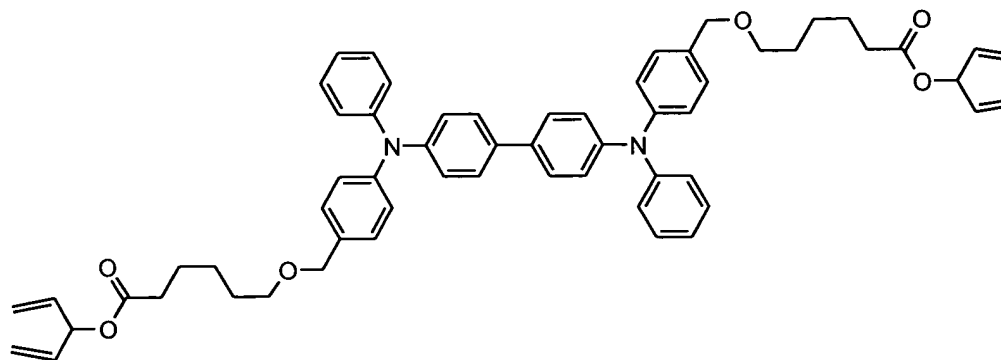
each D is independently selected from:



**[0014]** Examples of X-S<sub>1</sub>-Y-D may be selected from:

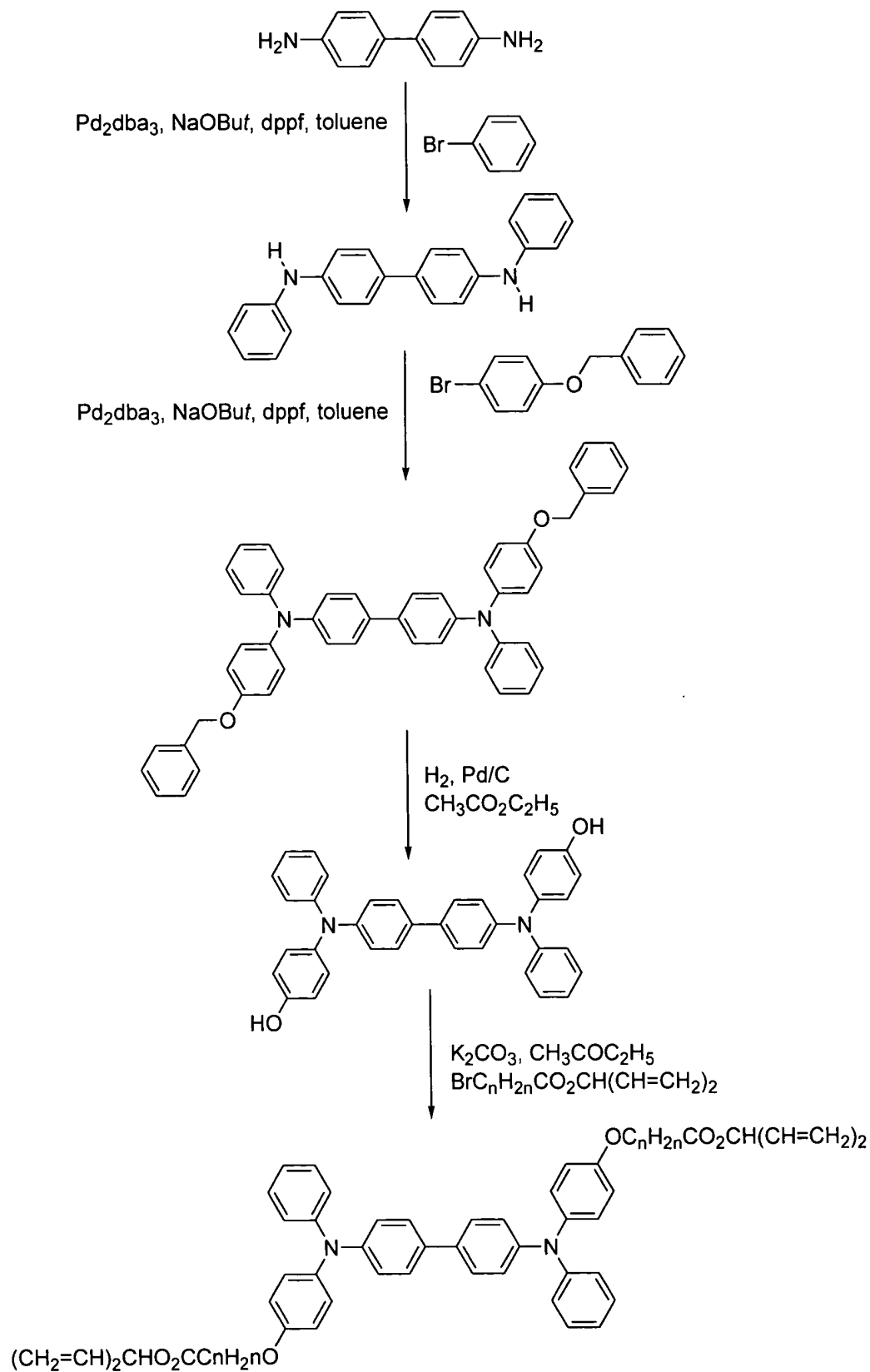


5 **[0015]** Examples of a reactive non-mesogenic compound include the compound of formula II:

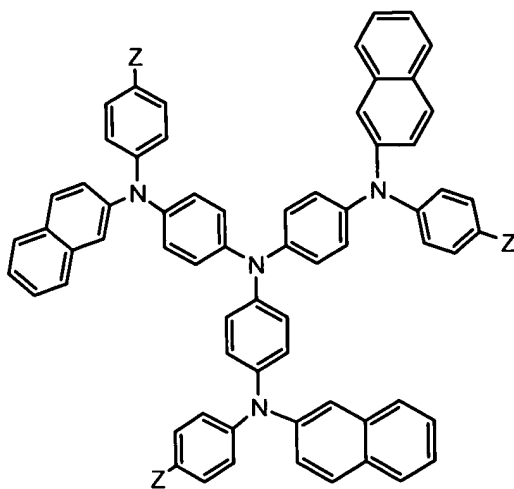


II.

**[0016]** Compounds of formula I and formula II (wherein n=5) could be prepared as  
 10 shown in the following scheme.



[0017] In another aspect, the present invention provides novel reactive non-mesogenic compounds of formula III:



III

5 wherein:

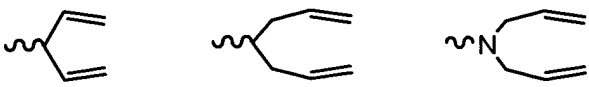
each Z is independently selected from X-S<sub>1</sub>-Y-D and H, provided that only one Z is H;

each X is independently selected from CH<sub>2</sub>O, CH<sub>2</sub>, and CH<sub>2</sub>NR, wherein R is selected from H, CH<sub>3</sub>, C<sub>2</sub>H<sub>5</sub>, n-C<sub>3</sub>H<sub>7</sub>, and i-C<sub>3</sub>H<sub>7</sub>; preferably CH<sub>2</sub>O;

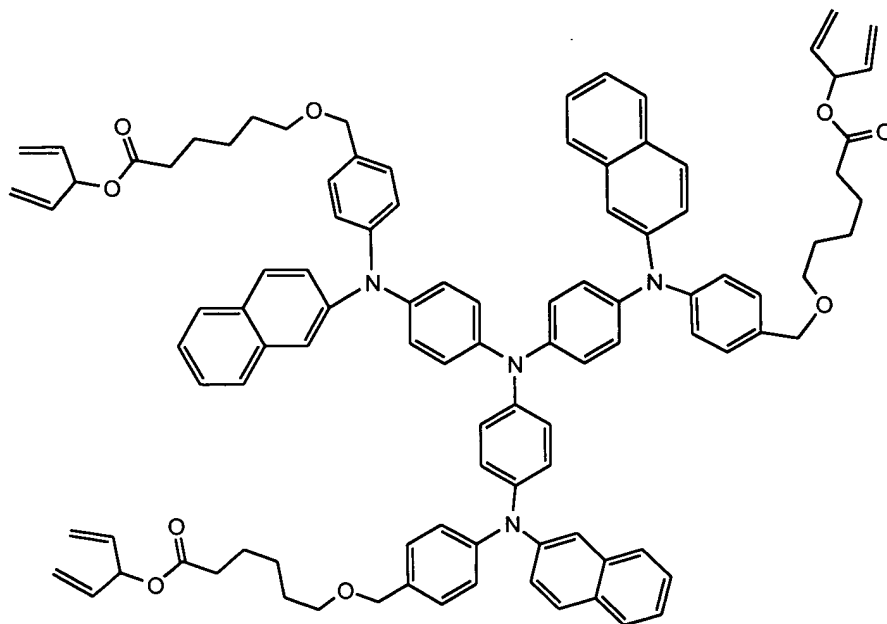
10 each S<sub>1</sub> is independently selected from an alkylene group (linear or branched) and an alkenylene group (linear or branched) having 2, 3, 4, 5, 6, 7, 8, 9, 10, or 11 carbon atoms;

each Y is independently selected from CH<sub>2</sub>, O, CO<sub>2</sub>, and S; preferably CO<sub>2</sub> and,

each D is independently selected from:

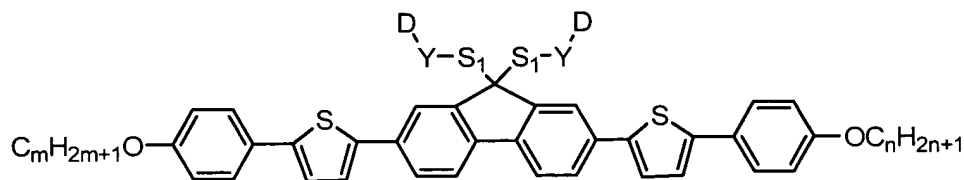
15 , provided that D forms other than an O-N, S-N, or N-N bond with spacer S.

[0018] Examples of a reactive non-mesogenic compound also include the compound of formula IV:



IV.

5 [0019] In another aspect, the present invention provides novel reactive non-mesogenic compounds of formula V:



V

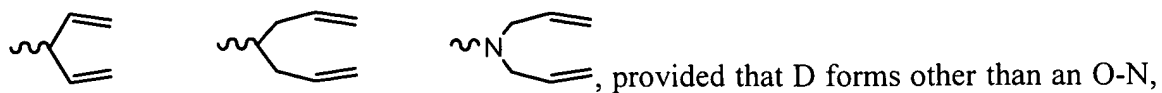
wherein:

10 each  $S_1$  is independently selected from an alkylene group (linear or branched) and an alkenylene group (linear or branched) having 2, 3, 4, 5, 6, 7, 8, 9, 10, or 11 carbon atoms;

each Y is independently selected from  $CH_2$ , O,  $CO_2$ , and S; preferably  $CO_2$ ;



each D is independently selected from:

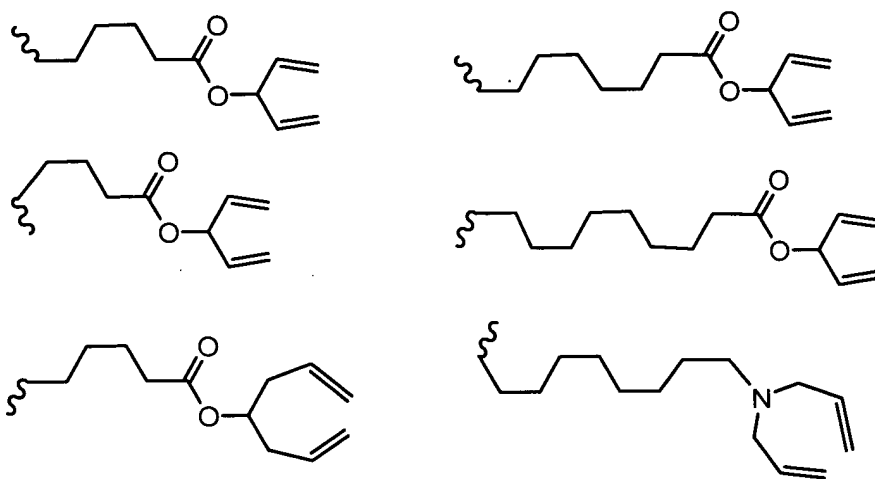


S-N, or N-N bond with spacer S;

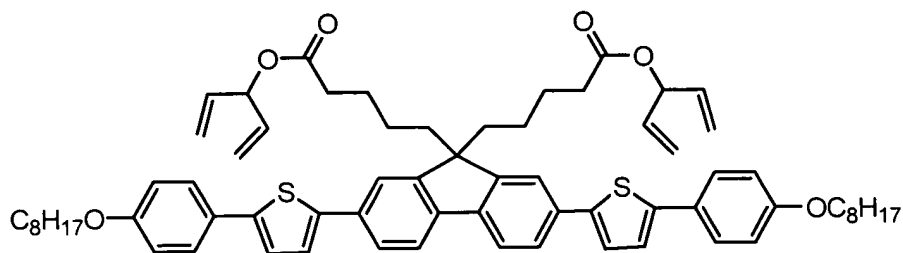
m is selected from 3,4,5,6,7, 8, 9, 10, and 11; and,

5 n is selected from 3,4,5,6,7, 8, 9, 10, and 11.

**[0020]** Examples of S<sub>1</sub>-Y-D may be selected from:



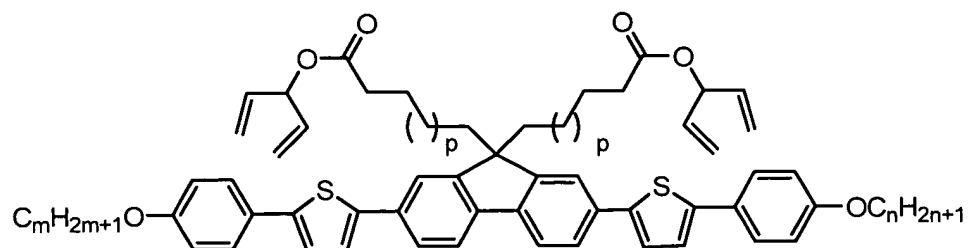
**[0021]** Examples of a reactive non-mesogenic compounds also include the compound of formula VI:



VI.

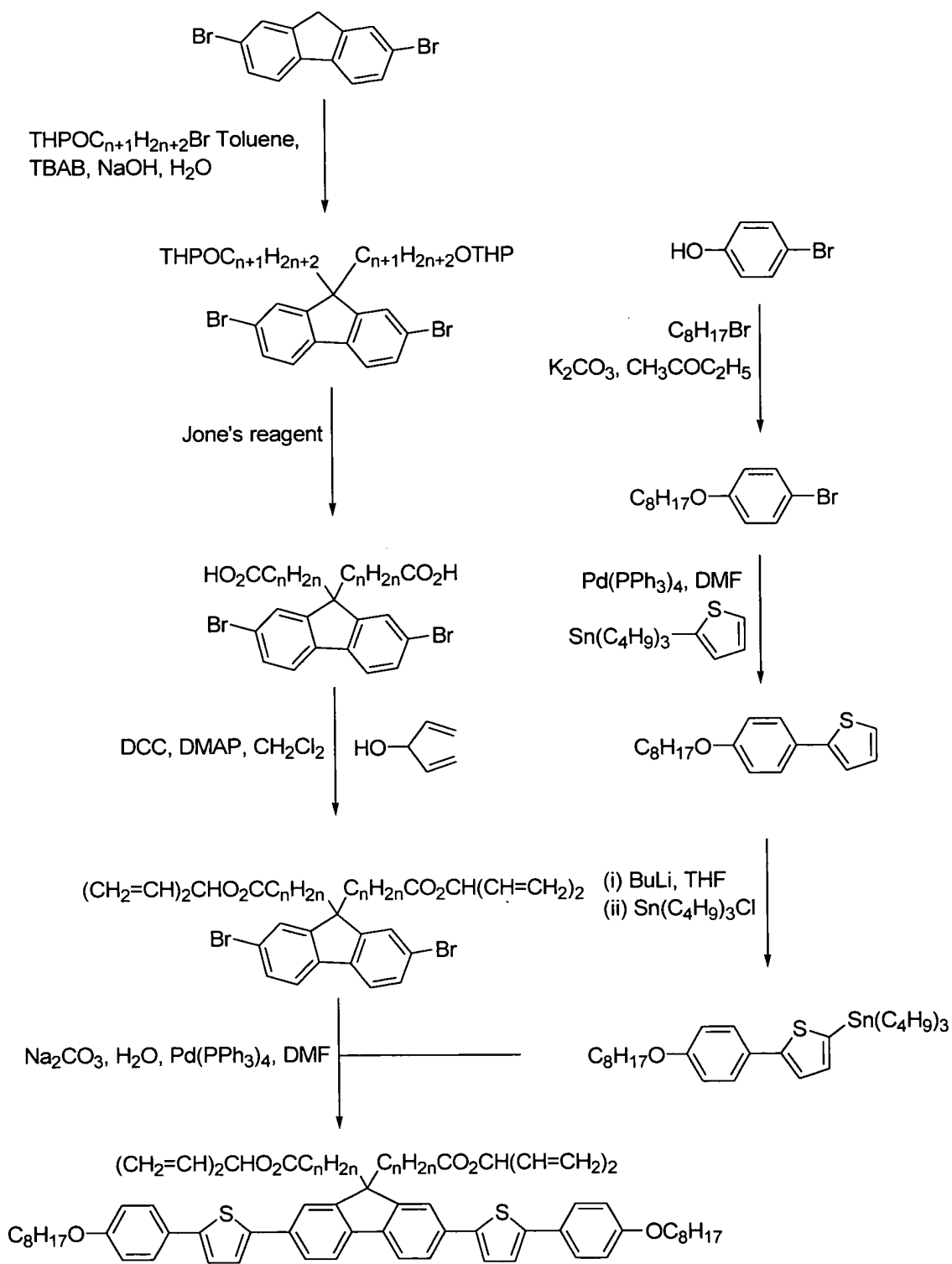
**[0022]** Additional examples of reactive non-mesogenic compounds are shown in Table 1:

Table 1

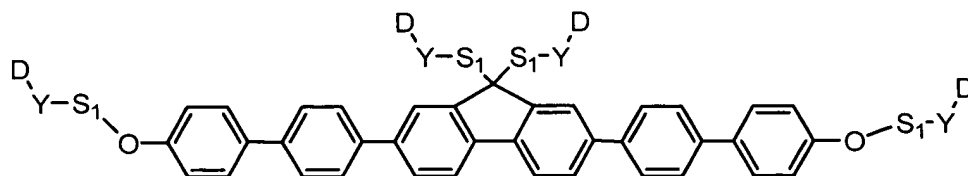


Formula	p	m	n
VIIa	2	8	8
VIIb	4	8	8
VIIc	8	8	8
VIIId	1	3	3
VIIe	1	4	4
VIIIf	1	5	5
VIIg	1	6	6.

**[0023]** Compounds of formula V-VIII could be prepared as shown in the following scheme.



**[0024]** In another aspect, the present invention provides novel reactive non-mesogenic compounds of formula VIII:



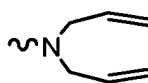
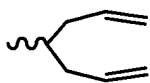
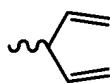
VIII

5 wherein:

each  $S_1$  is independently selected from an alkylene group (linear or branched) and an alkenylene group (linear or branched) having 2, 3, 4, 5, 6, 7, 8, 9, 10, or 11 carbon atoms;

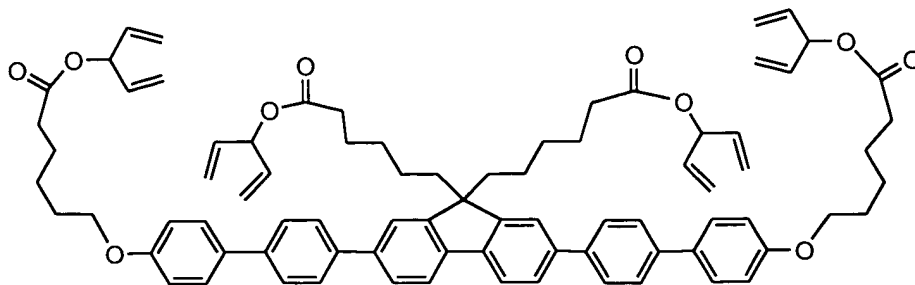
each Y is independently selected from  $CH_2$ , O,  $CO_2$ , and S; preferably  $CO_2$ ; and,

10 each D is independently selected from:



, provided that D forms other than an O-N, S-N, or N-N bond with spacer S.

**[0025]** Examples of a reactive non-mesogenic compounds also include the compound of formula IX

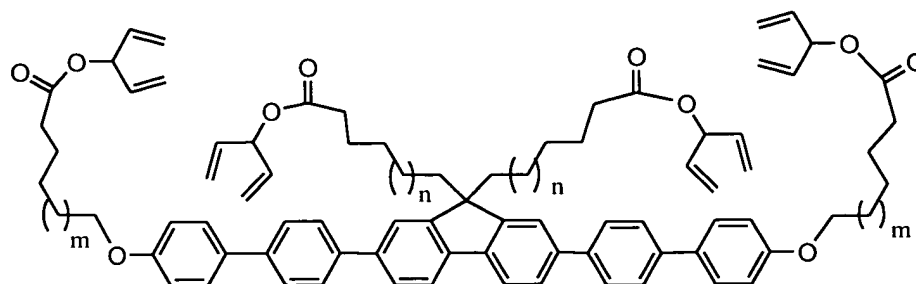


IX

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[0026] Additional examples of reactive non-mesogenic compounds are shown in Table 2

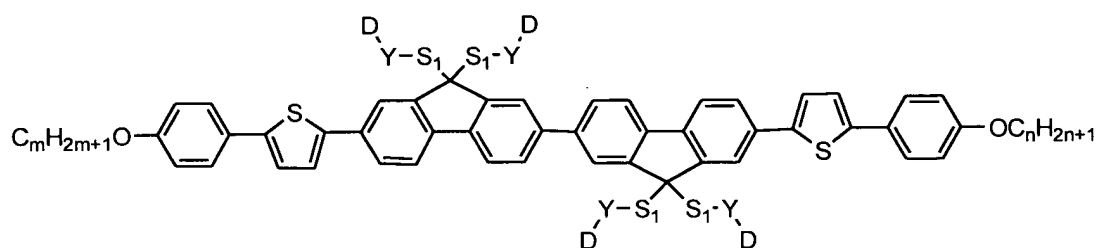
Table 2



Formula	n	m
Xa	1	3
Xb	1	7
Xc	3	1
Xd	3	3
Xe	3	7
Xf	7	1
Xg	7	3
Xh	7	7

5

[0027] In another aspect, the present invention provides novel reactive non-mesogenic compounds of formula Va:



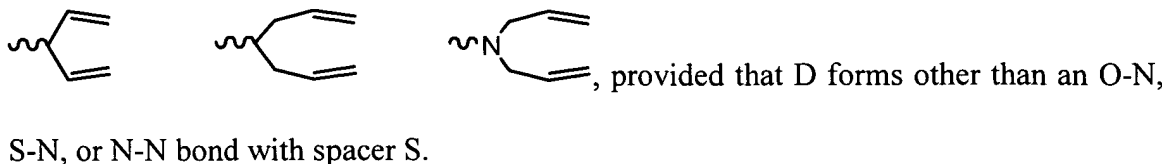
Va

10 wherein:

each  $S_1$  is independently selected from a  $C_{2-11}$  alkylene group and a  $C_{2-11}$  alkenylene group;

each Y is independently selected from CH<sub>2</sub>, O, CO<sub>2</sub>, and S; preferably CO<sub>2</sub>; and,

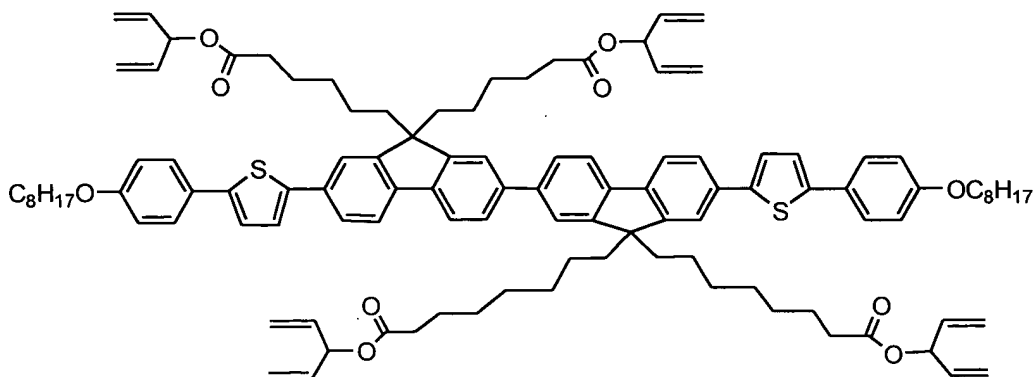
each D is independently selected from:



5           m is selected from 3,4,5,6,7, 8, 9, 10, and 11; and,

n is selected from 3,4,5,6,7, 8, 9, 10, and 11.

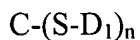
**[0028]**     Examples of reactive non-mesogenic compounds also include the compound of formula Vb:



10

Vb.

**[0029]**     In another aspect, the present invention provides a novel light emitting polymerizable material, comprising: a reactive discotic emitter compound having the following formula:



15     wherein:

C is a chromophore capable of forming a discotic liquid crystal;

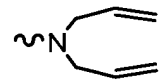
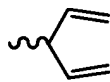
S is a spacer;

$D_1$  is H or is a non-conjugated diene susceptible to photopolymerization, provided that at least 2  $D_1$  are other than H; and,

n is selected from 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, and 20.

- 5 **[0030]** Chromophore C may be a phthalocyanine or porphyrin. The phthalocyanine or porphyrin may be bound to a metal. Spacer S may be an alkylene group (linear or branched) or alkenylene group (linear or branched) group having 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, or 21 carbon atoms. From 0, 1, 2, to 3 of the carbon atoms of spacer S are replaced by a heteroatom selected from O, S, and NR, wherein R is  
10 selected from H, CH<sub>3</sub>, C<sub>2</sub>H<sub>5</sub>, n-C<sub>3</sub>H<sub>7</sub>, and i-C<sub>3</sub>H<sub>7</sub>, preferably CH<sub>3</sub>, C<sub>2</sub>H<sub>5</sub>, n-C<sub>3</sub>H<sub>7</sub>, and i-C<sub>3</sub>H<sub>7</sub>. From 0, 1, to 2 carbon atoms of spacer S may be substituted by a carbonyl group.

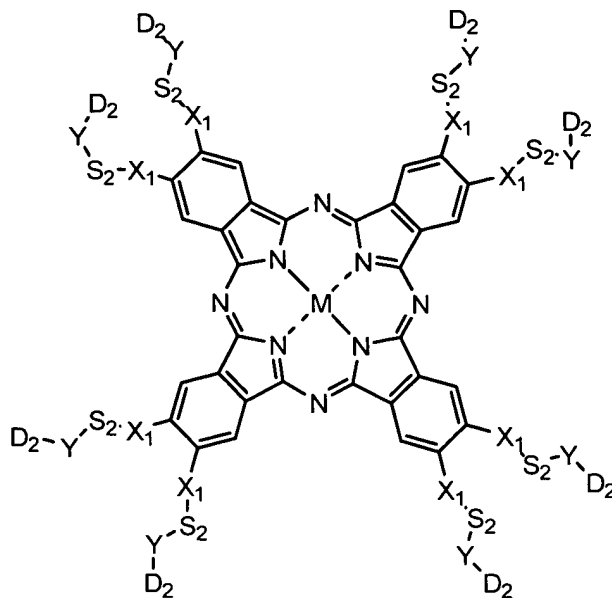
Diene  $D_1$  may be H or selected from:



provided that  $D_1$  forms other than an O-N, S-N, or N-N bond with spacer S, and further provided that at least 2  $D_1$  are other than H. Variable n may be selected from 4, 5, 6, 7,

15 and 8.

**[0031]** In another aspect, the present invention provides novel reactive discotic emitter compounds of formula XI:



XI

wherein:

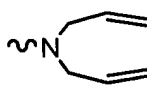
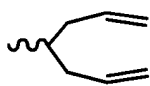
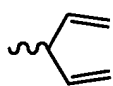
M is a suitable metal; preferably Pt;

- 5        each  $X_1$  is independently selected from O,  $CH_2$ , and NR, wherein R is selected from H,  $CH_3$ ,  $C_2H_5$ ,  $n-C_3H_7$ , and  $i-C_3H_7$ ; preferably O;

each  $S_2$  is independently selected from an alkylene group (linear or branched) and an alkenylene group (linear or branched) having 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, or 12 carbon atoms;

- 10        each Y is independently selected from  $CH_2$ , O,  $CO_2$ , and S; preferably  $CO_2$ ; and,

each  $D_2$  is independently  $C_{1-6}$  alkyl (linear or branched) or is selected from:

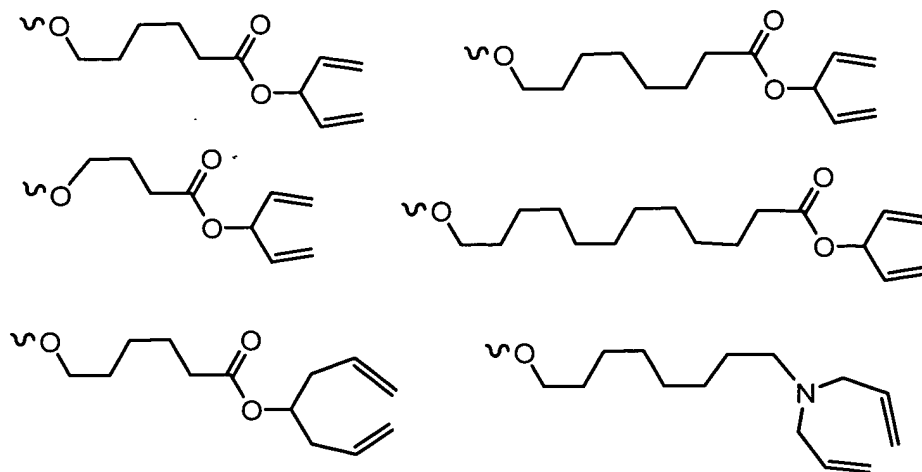


, provided that  $D_2$  forms other than an O-N,

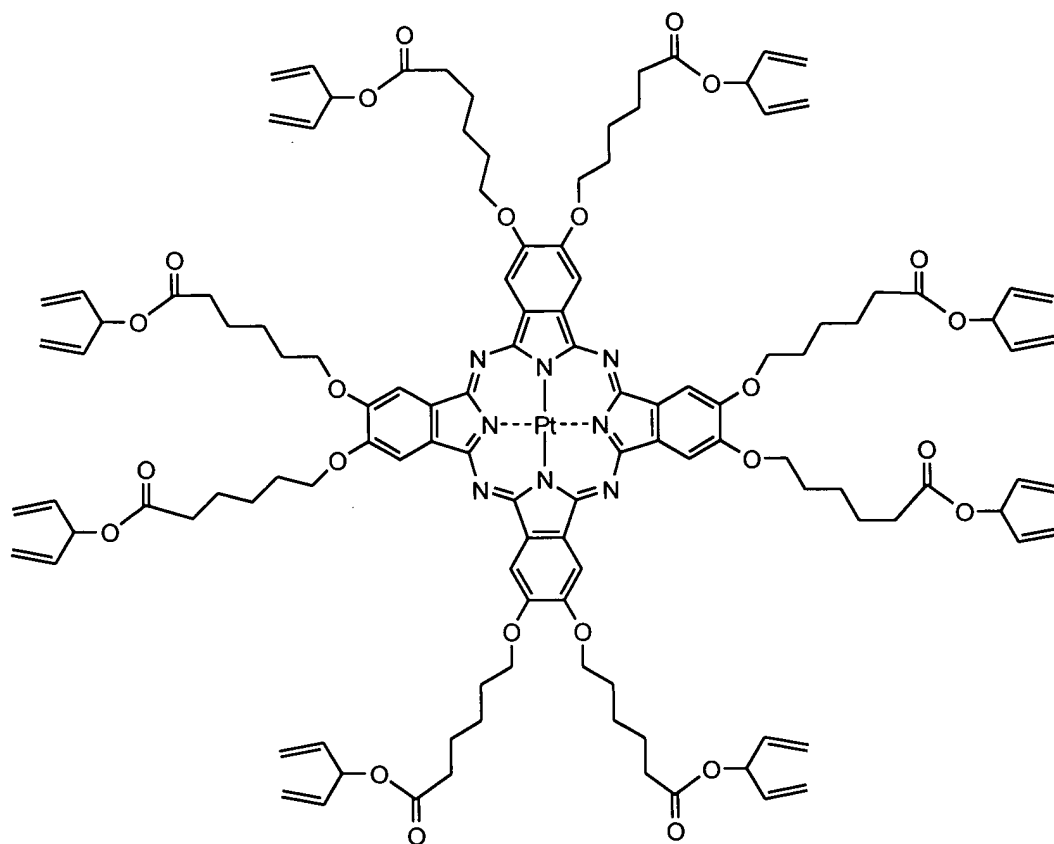
S-N, or N-N bond with spacer S, and further provided that at least two  $D_1$  are other than alkyl.



[0032] Examples of  $X_1-S_2-Y-D_2$  may be selected from:



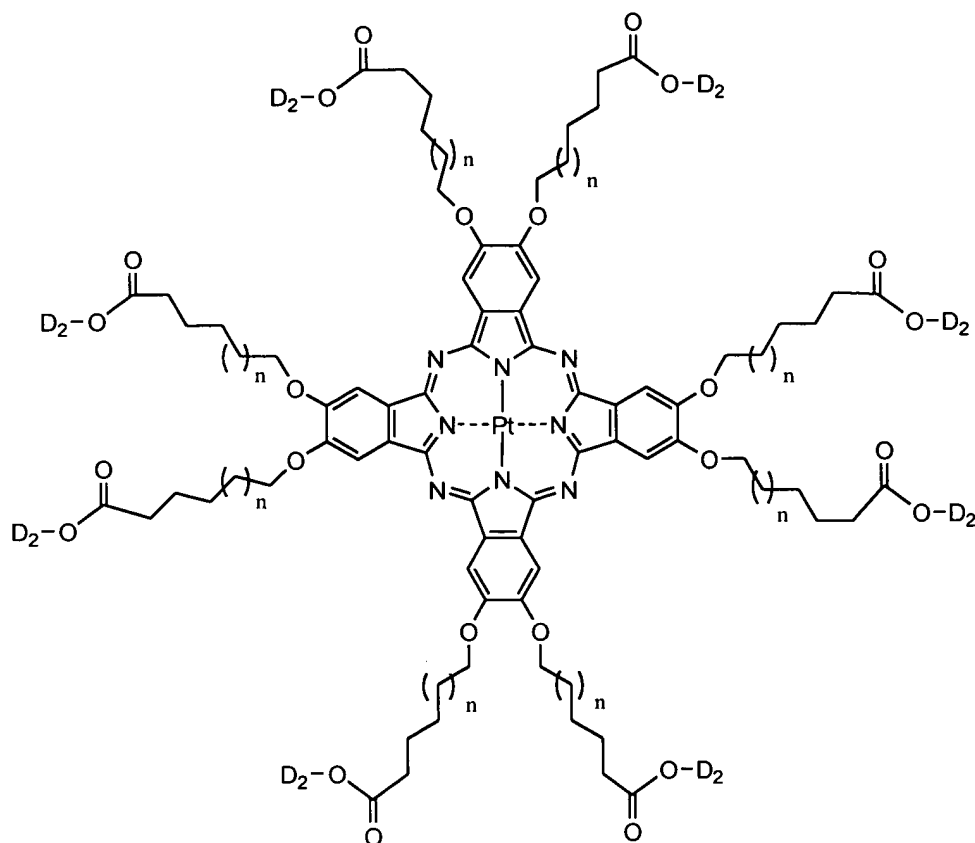
[0033] Examples of a reactive discotic emitter compounds include the compound of formula XII:



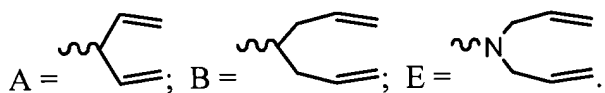
XII.

[0034] Additional examples of reactive discotic compounds are shown in Table 3

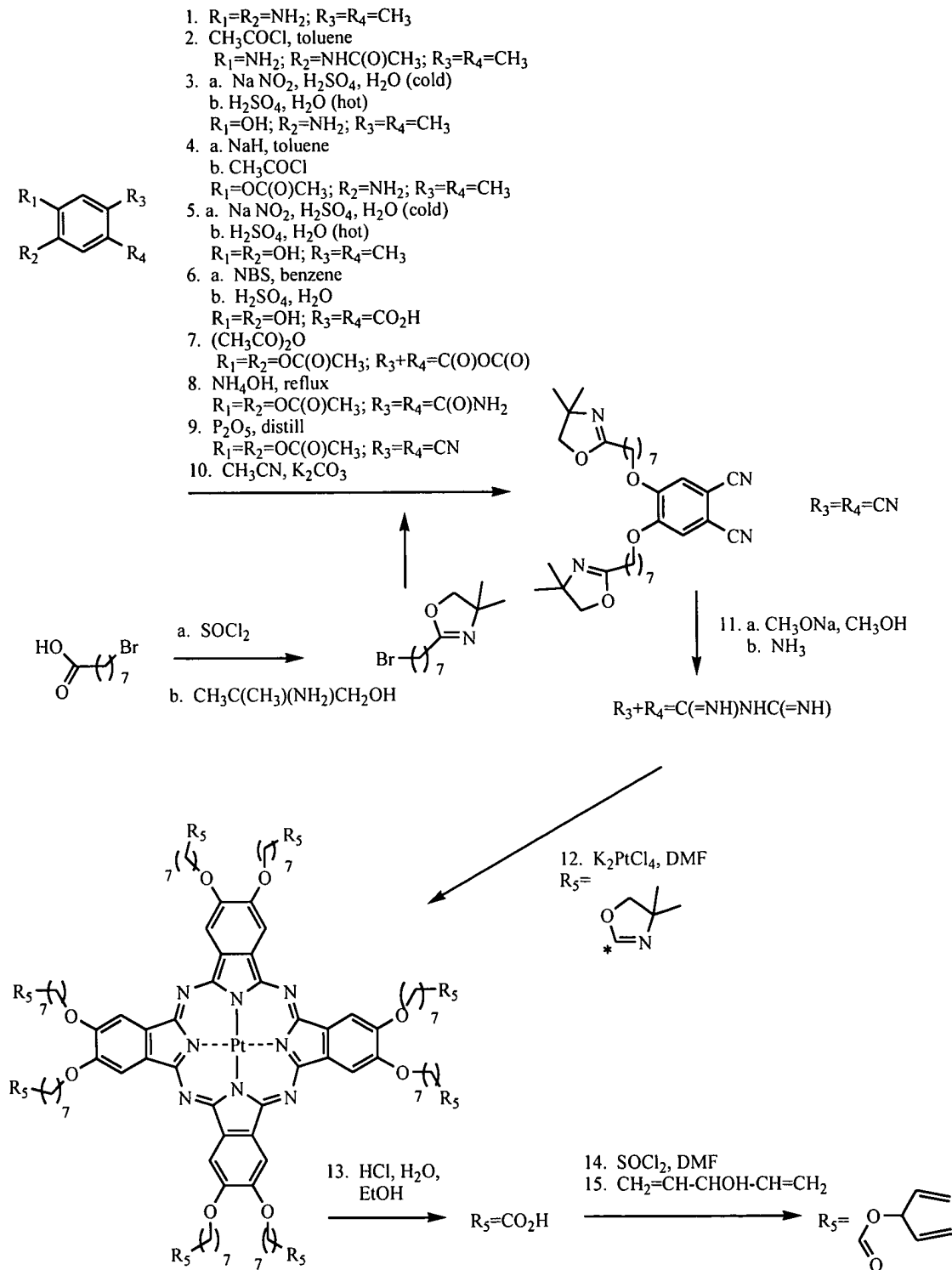
Table 3



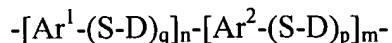
Formula	n	D <sub>2</sub>
XIIIa	1	B
XIIIb	1	E
XIIIc	2	A
XIIId	2	B
XIIIe	2	E
XIIIf	3	A
XIIIg	3	B
XIIIh	3	E



[0035] Compounds of formulae XI-XIII could be prepared as shown in the following scheme.



[0036] In another aspect, the present invention provides a novel light emitting polymerizable material, comprising: a reactive oligomeric or polymeric compound having the following formula:



5 wherein:

$\text{Ar}^1$  is a first aromatic group;

$\text{Ar}^2$  is a second aromatic group;

each S is independently a spacer;

each D is independently a non-conjugated diene susceptible to  
10 photopolymerization;

p is selected from 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10; preferably p is 2;

q is selected from 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10; preferably q is 0;

n is a mole fraction of  $[\text{Ar}^1-(\text{S-D})_q]$  in the oligomeric or polymeric backbone of from 0, 1, 2, 3, 4, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, to 90%;

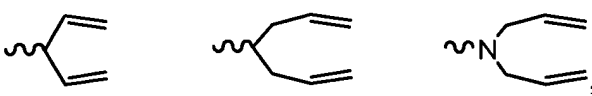
15 m is a mole fraction of  $[\text{Ar}^2-(\text{S-D})_p]$  in the oligomeric or polymeric backbone of 100-n%; and,

there are about 2, 3, 4, 5, 6, 7, 8, 9, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 160, 170, 180, 190, to 200 repeat units in the oligomeric or polymeric backbone, preferably, there are about 2, 3, 4, 5, 6, 7, 8, 9, 10, 20, 30, 40, 50, 60, 70, 80, 20 90, to 100 repeat units, and more preferably, there are about 20, 22, 24, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, to 50 repeat units;

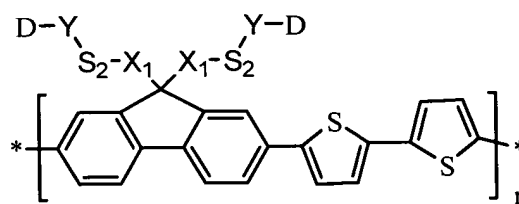
provided that p+q total at least 1;

further provided that when n is 0% then p is other than 0.

**[0037]** The oligomeric or polymeric compounds may be copolymers with two repeat units. Alternatively, the copolymers may have 3, 4, 5, or more repeat units. The copolymers may be random-sequence copolymers or ordered sequence copolymers (e.g., alternating or block).  $Ar^1$  and  $Ar^2$  may be selected from fluoren-diyl and bithien-diyl, preferably fluoren-2,7-diyl and 2,2'-bithien-5,5'-diyl. Spacer S is an alkylene group (linear or branched) or alkenylene group (linear or branched) group having 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, or 15 carbon atoms. From 0, 1, 2, to 3 of the carbon atoms of spacer S are replaced by a heteroatom selected from O, S, and NR, wherein R is selected from H,  $CH_3$ ,  $C_2H_5$ ,  $n-C_3H_7$ , and  $i-C_3H_7$ , preferably  $CH_3$ ,  $C_2H_5$ ,  $n-C_3H_7$ , and  $i-C_3H_7$ . From 0, 1, to 2 carbon atoms of spacer S are substituted by a carbonyl group. Diene D

may be selected from: , provided that D forms other than an O-N, S-N, or N-N bond with spacer S.

**[0038]** In another aspect, the present invention provides novel reactive oligomeric or polymeric compounds of formula XIV:



XIV

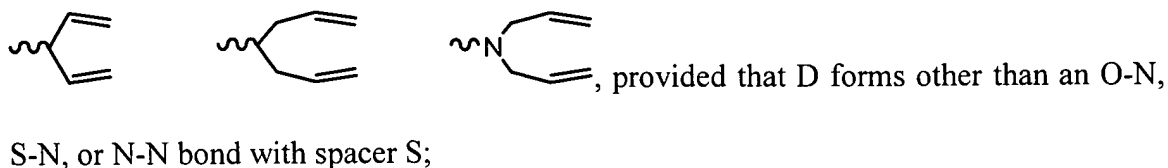
wherein:

each  $X_1$  is independently selected from O,  $CH_2$ , and NR, wherein R is selected from H,  $CH_3$ ,  $C_2H_5$ ,  $n-C_3H_7$ , and  $i-C_3H_7$ ; preferably O;

each  $S_2$  is independently selected from an alkylene group (linear or branched) and an alkenylene group (linear or branched) having 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, or 12 carbon atoms;

each Y is independently selected from  $CH_2$ , O,  $CO_2$ , and S; preferably  $CO_2$ ;

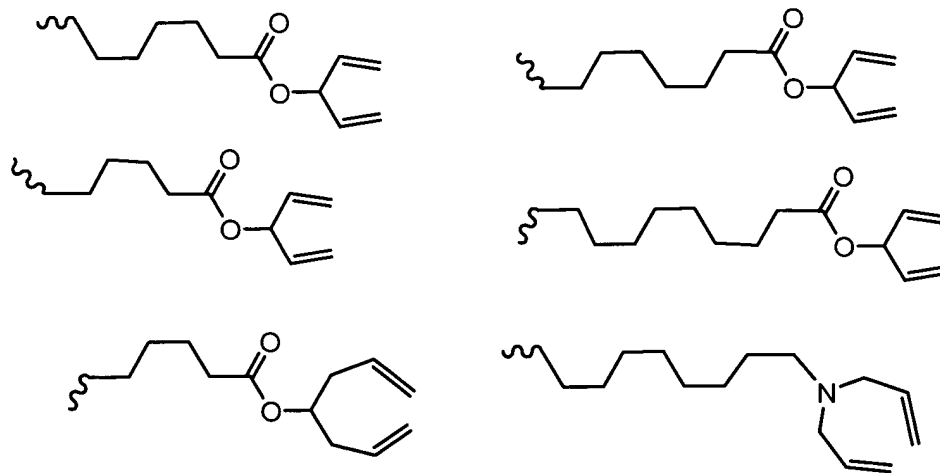
5 each D is independently selected from:



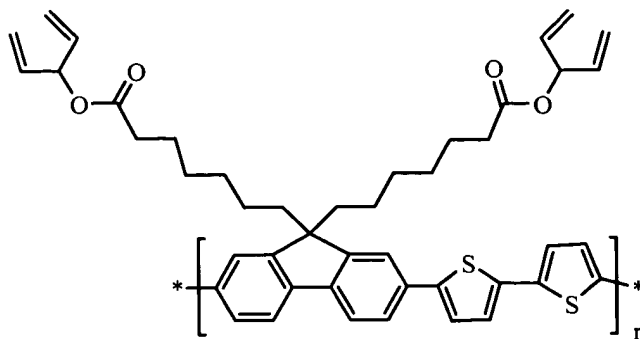
each \* is independently selected from H, OH,  $C_{1-12}$  alkyl (linear or branched),  $C_{1-12}$  alkoxy (linear or branched), and  $X_1-S_2-Y-D$ ; and,

10 r is selected from 2-100, preferably from 20-50.

**[0039]** Examples of  $X_1-S_2-Y-D$  are selected from:



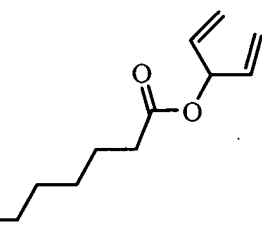
**[0040]** Examples of a reactive oligomeric or polymeric compound include those of formula XV:



XV

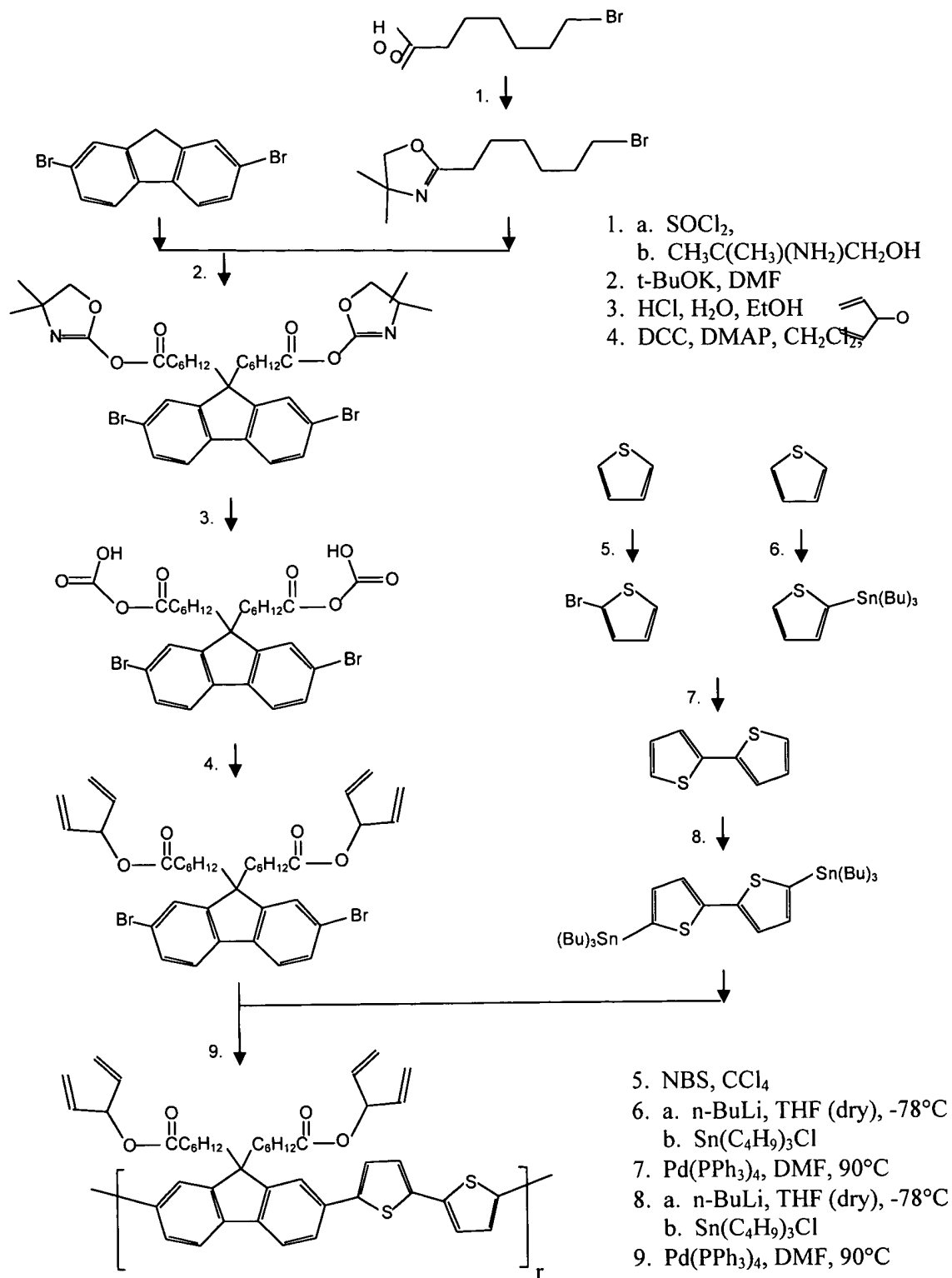
wherein:

each \* is independently selected from H, OH, C<sub>1-12</sub> alkyl (linear or branched),

- 5 C<sub>1-12</sub> alkoxy (linear or branched), and H<sub>2</sub>C—; and,
- r is selected from 2-100, preferably 20-50.

**[0041]** Compounds of formula XIV-XV could be prepared as shown in the following scheme.





[0042] In another aspect, the present invention provides a novel process for forming a charge-transport or light emitting layer, comprising: photopolymerizing the non-conjugated diene moieties of the materials of the present invention. Preferably, the photopolymerization occurs substantially without a photoinitiator. Preferably, the photopolymerization involves cyclopolymerization. The photopolymerizing may be conducted at room temperature. The photopolymerization may also utilize UV radiation.

[0043] The photopolymerization may involve radicalization of at least one of the dienes D (or D<sub>1</sub>) present in the materials of the present invention to form a radical, D<sup>•</sup>. The radicalized diene D<sup>•</sup> may then react with an unradicalized diene D (or D<sub>1</sub>) of a second compound to form a cyclic entity. This reaction may be sterically controlled. Preferably, radicalization is caused by UV photopolymerization.

[0044] In another aspect, the present invention provides novel, polymeric light emitting or charge transporting materials, comprising: a polymer formed from one of the present charge transporting or light emitting materials. The polymer may have 5, 6, 7, 8, 9, 10, 15, 20, 25, 30, 35, 40, 45, to 50 monomeric subunits. The polymer may be preferably formed by photopolymerization. The polymer may be substantially photoinitiator free. The polymer may be an insoluble, crosslinked network. Crosslinking occurs whenever at least a second diene present on the polymerizable material is attached to a polymer chain formed from polymerizable materials other than that to which the first diene is directly attached. Crosslinking may occur with from 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, to 100% of the polymerizable materials.

Preferably from 50-60% of the polymerizable materials are crosslinked. The polymer may be electroluminescent. The polymer may be aligned. The polymer may emit polarized light upon excitation, which is preferably linear polarized light. The novel, polymeric light emitting or charge transporting materials may, further comprise: a linear polarizer, wherein the linear polarizer has a polarization axis substantially aligned with a polarization of the linear polarized light.

[0045] The novel, polymeric light emitting, or charge transporting materials may, further comprise: photoactive dyes. The dye, preferably comprises: a dichroic or pleachroic dye. Examples include anthraquinone dyes or tetralines, including those described in S. M. Kelly, Flat Panel Displays: Advanced Organic Materials, RSC Materials Monograph, ed. J. A. Connor, [2000]. Different dopant types may be used to obtain different pixel colors.

[0046] In another aspect, the polymeric light emitting or charge transporting materials disclosed herein may also be prepared by copolymerization of mixtures of reactive compounds. These mixtures may include two, three, four, or more reactive compounds disclosed herein. Examples of these mixtures include, but are not limited to, (a) a mixture of first and second reactive non-mesogenic compounds each having the formula:  $C-(S-D)_n$ , wherein the first and second compounds are different; (b) a mixture of first, second, and third reactive non-mesogenic compounds each having the formula:  $C-(S-D)_n$ , wherein the first, second, and third compounds are different; (c) a mixture of first, second, third, and fourth reactive non-mesogenic compounds each having the formula:  $C-(S-D)_n$ , wherein the first, second, third, and fourth compounds are different; (d) a mixture of first and second reactive discotic compounds each having the formula:

C-(S-D<sub>1</sub>)<sub>n</sub>, wherein the first and second compounds are different; (e) a mixture of first, second, and third reactive discotic compounds each having the formula: C-(S-D<sub>1</sub>)<sub>n</sub>, wherein the first, second, and third compounds are different; (f) a mixture of first, second, third, and fourth reactive discotic compounds each having the formula: C-(S-D<sub>1</sub>)<sub>n</sub>, wherein the first, second, third, and fourth compounds are different; (g) a mixture of first and second reactive oligomeric or polymeric compounds each having the formula: -[Ar<sup>1</sup>-(S-D)<sub>q</sub>]<sub>n</sub>-[Ar<sup>2</sup>-(S-D)<sub>p</sub>]<sub>m</sub>-, wherein the first and second compounds are different; (h) a mixture of first, second, and third reactive oligomeric or polymeric compounds each having the formula: -[Ar<sup>1</sup>-(S-D)<sub>q</sub>]<sub>n</sub>-[Ar<sup>2</sup>-(S-D)<sub>p</sub>]<sub>m</sub>-, wherein the first, second, and third compounds are different; and, (i) a mixture of first, second, third, and fourth reactive oligomeric or polymeric compounds each having the formula: -[Ar<sup>1</sup>-(S-D)<sub>q</sub>]<sub>n</sub>-[Ar<sup>2</sup>-(S-D)<sub>p</sub>]<sub>m</sub>-, wherein the first, second, third, and fourth compounds are different. Alternatively, the copolymerization mixtures may include one or more reactive compounds disclosed herein and one or more other reactive compounds (e.g., the reactive mesogens of US2003/0099785, the contents of which are incorporated herein by reference). This may be advantageous in that eutectic or near eutectic mixtures of the reactive compounds may be prepared that are isotropic liquids or discotic fluids at room temperature. Liquids or fluids of these types are less likely to crystallize into solids before or after polymerization. Crystallization creates defect structures that greatly diminish the utility of OLED materials. Also, polymerization in a liquid or fluid phase may occur at lower UV doses and with higher crosslink conversion. Preferably, the copolymerization mixtures polymerize faster than the rates at which the individual components polymerization. More preferably, the copolymerization mixtures

photopolymerize faster than the rates at which the individual components photopolymerization.

[0047] For example, equal parts of the four compounds, derived from Compound XI with  $S_2$  is -butane-1,4-diyl; n-pentane-1,5-diyl; n-nonane-1,9-diyl; and n-decane-1,10-diyl;  $M=Pt$ ;  $X_1=O$ ;  $Y=CO_2$ ; and,  $D_1=1,4\text{-pentadien-3-yl}$  yields a mixture with a low crystal to discotic transition temperature that may be photocrosslinked to a polymeric solid with discotic order. As another example, equal parts of compounds VIIa, VIIb, and VIIc may be mixed together to form a low melting mixture and crosslinked by irradiation with the 325 nm radiation from a helium cadmium laser to yield a light emitting polymer with a highly homogenous structure.

[0048] Reactive compounds of this invention may also be copolymerized with other reactive compounds including reactive calamitic mesogens. In this aspect, the polymer formed may have a calamitic liquid crystalline structure. The material may have an aligned calamitic liquid crystalline structure. The material may be light emitting, preferably polarized light. A preferred reactive mesogen for copolymerization has the formula:



wherein:

A is a chromophore;  
each S is independently a spacer; and,  
each B is independently an endgroup that is susceptible to photopolymerization.

[0049] Chromophore A may be an aryl substituted fluorene, wherein from 0-2 hydrogen atoms on chromophore A are replaced by a group selected from deuterium, F,

and CH<sub>3</sub> and wherein the aryl substituents are located between the chromophore and each spacer S. Aryl substituted fluorene is intended to mean that the fluorene unit is substituted with 2 first aromatic rings, which are independently selected from phenyl, naphthyl, and 5-10 membered aromatic heterocycles consisting of carbon atoms and 0-4 heteroatoms selected from O, S, and NH. Examples of heterocycles include, but are not limited to, thienyl, pyridyl, pyridazinyl, pyrimidinyl, pyrazinyl, and triazinyl. Preferably, the first aromatic rings are phenyl or thienyl. It is also preferable that the first aromatic rings are themselves independently substituted with a second aromatic ring and spacers S are each independently attached to the second aromatic rings. The second aromatic rings are independently selected from phenyl, naphthyl, and 5-10 membered aromatic heterocycles consisting of carbon atoms and 0-4 heteroatoms selected from O, S, and NH. Preferably, the second aromatic rings are phenyl or thienyl. It is also preferably that the second aromatic rings are independently substituted with a third aromatic ring and spacers S are each independently attached to the third aromatic rings. The third aromatic rings are independently selected from phenyl, naphthyl, and 5-10 membered aromatic heterocycles consisting of carbon atoms and 0-4 heteroatoms selected from O, S, and NH. Preferably, the third aromatic rings are phenyl or thienyl. The aryl substituted fluorene may be substituted with 0-2 groups selected from C<sub>1-12</sub> alkyl (branched or linear), C<sub>1-12</sub> alkenyl (branched or linear), and C<sub>1-12</sub> alkoxy (linear or branched). Spacer S may be an alkylene (linear or branched) or alkenylene (linear or branched) group having 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, or 15 carbon atoms. From 0, 1, 2, to 3 of the carbon atoms of spacer S are replaced by a heteroatom selected from O, S, and NR, wherein R is selected from H, CH<sub>3</sub>, C<sub>2</sub>H<sub>5</sub>, n-C<sub>3</sub>H<sub>7</sub>, and i-C<sub>3</sub>H<sub>7</sub>, preferably CH<sub>3</sub>, C<sub>2</sub>H<sub>5</sub>, n-C<sub>3</sub>H<sub>7</sub>, and i-C<sub>3</sub>H<sub>7</sub>.



500 $\mu$ m. In microdisplays, the pixels may have a size of from 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 15, 20, 25, 30, 35, 40, 45, to 50  $\mu$ m, preferably from 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, to 15 $\mu$ m, even more preferably from 8, 9, to 10  $\mu$ m. In other displays, the pixel size is typically larger with a size of about 300  $\mu$ m being typical. Pixel color may also be  
5 influenced by the choice of chromophore with different chromophores having more suitability as red, green, or blue pixels.

[0052] In another aspect, the present invention provides a novel device, comprising: a material layer of the present invention. The device may be selected from an electronic device, a light emitting device, an organic light emitting device, a lighting element, a  
10 photovoltaic cell, and a laser. This aspect also includes a process, comprising: applying a material to a surface and then photopolymerizing the material in situ to form a polymeric layer. A useful method of applying the photopolymerizable materials is by spin-coating. Preferably, the surface is an inert substrate (e.g., glass or plastic). Particularly useful substrates are glass, indium tin oxide coated glass, an alignment layer  
15 coated over glass, and an alignment layer coated over an indium tin oxide coated glass. Layer thicknesses are typically in the range of 10, 20, 30, 40, 50, 100, 150, 200, 250, 300, 350, 400, 450, to 500 nm and are preferably in the range of 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 160, 170, 180, 190, to 200 nm. The devices may further comprise: additional layers including, but not limited to a light emitting layer, hole  
20 transport layer, electron transport layer, and a photoalignment layer. When the material of the present invention comprises a charge transport compound, then it is preferable to have a light emitting layer present. When the material of the present invention comprises a light emitting compound, then it is preferable to have a charge transport layer present.



This aspect may also include a device, comprising: a photopolymerizable material applied over a photoalignment layer (e.g., the surface is a photoalignment layer), and the process for forming the same. This could be the case, for example, when mixtures of the reactive compounds of the present invention and reactive calamitic mesogens are used to give a composite material that shows a calamitic phase. This aspect may also include a device, comprising: a photopolymerizable material applied over a photoalignment layer (e.g., the surface is a photoalignment layer), which in turn is applied over an indium tin oxide coated glass, and the process for forming the same. The photoalignment layer may, further comprise: a transport compound (e.g., ion transport, hole transport, or electron transport), if desired.

**[0053]** FIG. 1 illustrates an exemplary device 100 including transport layers and an emissive layer. In FIG. 1, the device 100 includes a transparent substrate 102, an anode 104, a hole injection layer 106, a hole transport layer 108, an emissive layer 110, an electron transport layer 112, an electron injection layer 114, and a reflective cathode 116. The anode 104, hole injection layer 106, hole transport layer 108, emissive layer 110, electron transport layer 112, electron injection layer 114, and reflective cathode 116 form an organic light emitting device (OLED) 118. The anode 104 may be made from indium-tin oxide or another suitable transparent, conductive material. The cathode 116 may be made from a reflective, low work function metal such as aluminum, magnesium/silver alloy, calcium, or another suitable material. Alternatively, the device may be transmissive. The materials disclosed herein may be used to form, for example, one or more of the hole transport layer 108, the emissive layer 110, and the electron transport layer 112. The other layers may be formed from any of the suitable materials that are

known in the art. Alternatively, additional layers, such as a photoalignment layer, may be included in the device 100 and one or more of the illustrated layers may be omitted.

[0054] In another aspect, the present invention provides a novel multicolor emitter, comprising: arrangements or sequences of different pixel colors. One suitable multicolor emitter, comprises: stripes of red, green, and blue pixels having the same polarization state. This may be used as a sequential color backlight for a display which allows the sequential flashing of red, green, and blue lights. Such backlights may be used in transmissive Ferroelectric Liquid Crystal (FLC) displays where the FLC acts as a shutter for the flashing colored lights. Alternatively, the shutter may be formed from other kinds of liquid crystal materials or may be used formed from non-liquid crystalline materials. Another suitable multicolor emitter, comprises: a full color pixellated display in which the component pixels thereof have the same or different alignment. Suitable multicolor emitters may be formed by a sequential “coat, selective cure, wash off” procedure in which a first color emitter is applied to an aligned layer by a suitable coating process (e.g. spin coating). The coated first color emitter is then selectively cured only where pixels of that color are to be formed. The residue (of uncured first color emitter) is then washed off. A second color emitter is then applied to the aligned layer, cured only where pixels of that color are required, and the residue washed off. If desired, a third color may be applied by repeating the procedure for the third color. This procedure may be used to form a pixellated display such as for use in a color emissive display. This procedure is simpler than traditional printing (e.g. ink jet) methods of forming such displays.

[0055] Although several embodiments of the present invention and its advantages have been described in detail, it should be understood that changes, substitutions,

transformations, modifications, variations, permutations, and alterations may be made therein without departing from the teachings of the present invention or the spirit and scope of the invention being set forth by the appended claims.